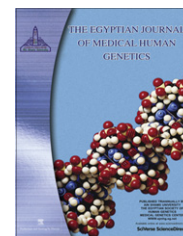




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ORIGINAL ARTICLE

Effect of vibration versus suspension therapy on balance in children with hemiparetic cerebral palsy

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Abstract Most cerebral palsy children have deficits in balance, co-ordination, and gait throughout childhood and adulthood. So, it is essential to seek an ideal physical therapy program to help in solving such widespread problem. The present study was conducted to compare between the effect of vibration training and suspension therapy on balance in children with hemiparetic cerebral palsy. *Patients and methods:* Thirty children born with hemiparetic cerebral palsy from both sexes ranging in age from eight to ten years old were assigned into two groups of equal number. Study group I received vibration training in addition to a designed physical therapy program and study group II received suspension therapy in addition to the same physical therapy program given to the study group I. Stability indices were evaluated via using Biodex instrument system before and after six months of treatment.

Results: The results revealed no significant difference when comparing the pre-treatment mean values of the two groups (study I and study II), while significant improvement was observed in all the measuring variables of the two groups when comparing their pre and post treatment mean values. Significant difference was also observed when comparing the post treatment results of the two groups in favor of the study group II.

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Conclusion: Suspension therapy for children with hemiparetic cerebral palsy is an excellent supplement to regularly scheduled physical therapy intervention for the purpose of improving degree of stability in those patients.

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1. Introduction

Cerebral palsy (CP) is the most common cause of severe physical disability in childhood. The large majority of children with CP have difficulty in walking. Improving the ability to walk or perform other functional activities are often the primary therapeutic goals for children with CP [1]. Adaptive measures that try to compensate for reduced mobility consume a large proportion of the costs related to CP [2]. Measures that improve mobility in children with CP therefore potentially could result in substantial savings for health care systems. One factor contributing to impaired walking ability is muscle weakness [3]. Muscle weakness in turn is commonly associated with abnormal bone development, leading to increased susceptibility to fractures [4]. A recent task force of experts in the field of CP identified the prevention and treatment of secondary conditions such as muscle weakness and bone fragility as critical areas of future research on CP [5]. Muscle strengthening thus might be useful for improving both motor function and bone development in children with CP. A method for muscle strengthening that is increasingly used in a variety of clinical situations is whole-body vibration (WBV) [6,8]. Some studies have also found that WBV can increase bone mineral density [7]. WBV is practiced on a vibrating platform on which the user is standing in a static position or moving in dynamic movements. Balance control is important for competence in the performance of most functional skills, helping children to recover from unexpected balance disturbances, either due to slips and trips or to self-induced instability when making a movement that brings them toward the edge of their limit of stability [9]. Difficulties in determining individual causes of balance impairment and disability are related to the diverse mechanisms involved. Decreased muscle strength, range of movement, motor coordination, sensory organization, cognition, multisensory integration and abnormal muscle tone contribute to balance disturbances at different levels [10]. Suspension therapy is an innovative and effective modality for treatment. It can be combined with conventional physical therapy methods and can be successfully combined with most of rehabilitation and sport equipment to give postural stability while promoting independence with security which significantly improves balance and coordination of the body and the performance of the vestibule system, also, it allows more full use of the patient's strength and abilities [11]. Biodex stability system is an important balance assessment and training system. In addition, it is the unique device, which is designed to stimulate joint mechanoreceptors and to assess the neuromuscular control by quantifying the ability to maintain dynamic postural stability. This system also acts as a valuable training device to enhance the kinesthetic ability [12]. A clinical trial was conducted to compare between the effect of whole body vibration and suspension therapy via using spider cage in hemiparetic cerebral palsied children who were unable to maintain balance. The main hypothesis was that the treatment would improve balance function in these patients. The second-

ary hypotheses were that WBV and suspension would lead to an increase in balance in hemiparetic cerebral palsy children.

2. Patients, randomization and methods

2.1. Patients

Thirty children with hemiparetic cerebral palsy from both sexes between the ages of 8 and 10 years ($X' 8.92 \pm 0.73$ years) were recruited to participate in the study via the out-patient clinic of Physical Therapy Faculty, Cairo University. Their height ranged between 111 and 124 cm ($X' 117 \pm 0.07$ cm). They had sufficient cognition and were able to understand commands given to them. They were able to stand and walk independently with frequent falling. Patients who had balance problems were included in this study as confirmed by tilt board balance test which was performed under two conditions, tilting board eyes opened and tilting board eyes closed. Child was considered to have balance problems when the average sum of the maximum degrees of tilt in four directions (anterior-posterior and medial-lateral) done with both, eyes opened and eyes closed were less than 32.1 and 25.8 degrees respectively [13]. Exclusion criteria were the presence of any medical conditions that would severely limit a child's participation in the study as vision or hearing loss, cardiac anomalies or musculoskeletal disorders. Neither race nor sex precluded children from being enrolled in the study. Patients were classified randomly into two groups of equal number study group I who received whole-body vibration and study group II who received suspension therapy via using spider cage. In addition the two groups received their exercises therapy program as usual to facilitate postural control and balance.

2.2. Randomization

Patients were randomized in equal number to either continue the regular physiotherapy program to receive vibration therapy or suspension therapy in addition to the physiotherapy program offered by the faculty staff. The randomization was stratified according to GMFCS level to ensure similar functional levels in both study groups. Following the baseline evaluation of each child, a closed envelope was randomly selected that contained the child's group allocation. The treatment allocation was disclosed to the child and the parents immediately after the baseline evaluation. Blinding of study participants and therapists is not possible with the WBV system or the suspension therapy used in this study, as the vibration or suspension produced by the device is easily observable.

2.3. Methods

All procedures were explained to parents and participants, each of them signed a consent form prior to participation. Participants came to the out-patient clinic six times/week for six months successively. Test sessions lasted approximately

15 min and practice sessions lasted one hour. Each group received exercises program for balance and posture control for 30 min in addition to 30 min suspension training for study group I and 30 min suspension therapy for study group II.

2.3.1. Test session

Biodex stability system was used to assess balance and postural stability. Each child in the two groups was asked to stand on the center of locked platform within the device with two legs stance while grasping the handrails, the display screen was adjusted so that each participant can look straight at it. At first, certain parameters were fed to the device.

1. Child's weight, height and age.
2. Stability level (platform firmness).

Then each participant was asked to achieve a centered position in a slightly unstable platform by shifting his/her feet position until it was easy to keep the cursor (representing the center of the platform) centered on the screen grid while standing in comfortable upright position. Once the participant was centered, the cursor was in the center of the display target, he/she was asked to maintain his/her feet position till stabilizing the platform. Heels coordinates and feet angles from the platform were recorded as follows: heels coordinates were measured from the center of the back of the heel, and foot angle: was determined by finding a parallel line on the platform to the center line of the foot. The test began after introducing feet angles and heels coordinates into the Biodex system. The platform advanced to an unstable state, then the child was instructed to focus on the visually feedback screen directly in front of him while both arms at the side of the body without grasping handrails and attempted to maintain the cursor in the middle of the bulls eye on the screen. Duration of the test was 30 s for each participant and the mean of the three repetitions was determined. A print out was obtained at the end of each test including overall stability index, antero-posterior stability index, and medio-lateral stability index. The high values mean that the child had balance difficulty. This test procedure was carried out for each child of the two groups before and after six months of treatment programs.

NB: A familiarity session occurred prior to the test session. This session was particularly necessary for participants with CP to ensure their comfort with the research team and protocol. On this session, participants practiced whole body vibration and exercises within spider cage. Also, an explanatory session on the Biodex instrument system was conducted to be aware of the different test steps.

2.3.2. Treatment protocol

2.3.2.1. For the study group I. All patients continued to receive physiotherapy according to the program established at the outpatient clinic of Faculty of Physical Therapy, Cairo University, regardless of treatment allocation. The physiotherapy program offered by the faculty staff was individualized according to the needs of each child and comprised six therapeutic sessions per week. The WBV treatment was administered in one-on-one sessions by one of the two fully trained physiotherapists. These two study physiotherapists were instructed in WBV therapy by one of the investigators (faculty staff). Adherence to study treatment procedures was ensured through regular interaction between this investigator and the study physiotherapists. For

the WBV treatment, a commercially available WBV device was used (Vibraflex Home Edition II®, Orthometrix Inc, White Plains, NY. Outside of North America, the brand name Galileo Basic® is used for this equipment). This device has a motorized board that produces side-to-side alternating vertical sinusoidal vibrations around a fulcrum in the mid-section of the plate. The frequency of the vibrations can be selected by the user. The patient stands on the board with both feet. The feet are placed at an equal distance from the center of the board. The peak-to-peak displacement to which the feet are exposed increases with the distance of the feet from the center line of the vibrating board. Three positions are indicated on the vibrating board, marked as '1', '2' and '3', which correspond to peak to-peak displacements of 2 mm, 4 mm and 6 mm.

The treatment schedule was adapted from published observational studies that had used the same WBV system as the present study to treat children with neuromuscular diseases and bone fragility disorders [14,15]. Each WBV session consisted of the following schedule: (3 min of WBV) – (3 min rest) – (3 min of WBV) – (3 min rest) – (3 min of WBV). Thus, one treatment session corresponded to 9 min of exposure to WBV. The study physiotherapist documented the vibration settings used for each treatment session as well as other clinical observations made during the vibration sessions. The physiotherapist was instructed to terminate the session if the child complained of fatigue or pain. In order to get acquainted with WBV treatment and to evaluate the child's capacity to be vertical on the plate, all patients performed the first treatment sessions using a vibration platform attached to the base of a tilt table. The identical set-up has previously been described as 'Cologne Standing and Walking Trainer System Galileo' [14,15]. The patient was positioned on the tilt table with the feet touching the vibration plate. The patients wore shoes during the WBV sessions to have a more stable position on the vibration plate. The patient was initially attached to the tilt table with two straps, one at the level of the pelvis and the other on the level of the knees. The initial tilt angle was set to 35 degrees. The goal for the subsequent sessions was to increase the angle of the tilt table and to eventually perform the WBV without a tilt table, using a WBV device placed on the ground. The speed of the progress toward this goal depended on the child's ability to maintain an upright posture under the conditions of WBV. The first treatment sessions were performed using a vibration frequency of 12 Hz, with the middle toe of each foot placed 5.5 cm from the neutral axis of the vibration plate (indicated as position '1' on the WBV device). The peak acceleration exerted by vibration increases with the frequency and the amplitude of the vibration. Therefore, higher frequency and higher amplitude are likely to elicit higher musculoskeletal force in the user of the WBV device. The goal was to increase the vibration frequency to 18 Hz and the peak-to-peak displacement to 4 mm (as determined for the middle toe of each foot). These target settings correspond to a peak acceleration of approximately 2.6 g and were based on our previous experience from a small observational study which indicated that these settings are usually well tolerated by children with CP [16]. The protocol foresaw to increase the WBV frequency in steps of 0.5 Hz every two treatment sessions until the target frequency of 18 Hz was attained. The actual speed of the increase in WBV frequency depended on the child's tolerability of the vibration. The frequency was increased only if the child felt comfortable with the setting.

Once the frequency of 18 Hz was reached, the feet were gradually placed wider apart until they were vertically below the hip joint. Thus, the middle toe of each foot was eventually placed between 8 cm and 11 cm from the neutral axis of the vibration plate, depending on the width of the child's pelvis. Whether using the tilt table or the ground-based WBV system, the patients flexed their knees and hips between 10 and 45 degrees (to prevent the vibration from extending up to the head). Guided by the study physiotherapist, the patients shifted their weight from side to side or increased and decreased the knee and hip angle. Other exercises included weight shift with rotation of the trunk, and alternate flexion and extension of knees. Postural correction was encouraged through visual feedback (by performing the treatment in front of a mirror) and through the therapist's verbal cueing. Treatment adherence was calculated as the ratio between the total time of WBV treatment received and the time of WBV exposure scheduled as per study protocol.

2.3.2.2. For the study group II. The children received a designed physical therapy program inside the "spider cage". Each child was placed in standing position in the center of the cage. He/she was hooked up in the spider cage by means of a belt around his/her waist that attached to the cage using elastic cords. The belt was fixed around his trunk by Velcro straps. The elastic cords were applied in a spider shape. This suspension system "spider cage" provides horizontal and vertical dynamic features of functional suspension as a support, assistance, or even resistance during training. The suspension system also provides just the right amount of support needed for securing and balancing patient while practicing or performing needed movements [17]. Different types of exercises were applied according to the level of the cords.

1. Cords beside: In which the level of the cords connection to the cage is at the same level of the cords connection to the belt so that the whole weight of the body falls on the lower limbs to give a chance for full weight bearing. At first, tension of cords was equal to each other. This enables the child to assume mid or upright position. Then the tension of cords was decreased gradually. The cords should be elastic enough to allow the child to re-adjust himself and to develop his own control. The tension of the front and back cords was interchangeably decreased while repeating the same exercises. Different exercises were applied to improve balance from different positions including; high kneeling, half kneeling, kneel-walking, stoops and recover, standing weight shift, squatting from standing position (squat balance), kicking ball, throwing ball, stepping, jumping in place, jumping abroad, standing on one foot and standing on balance board.
2. Full suspension: In this type the level of the cords connection to the cage is above the level of the cords connection to the belt in which the child is fully suspended (the child's feet are off the ground). This type of suspension used as vestibular stimulation, to provide body awareness and to promote or develop postural reflexes (protective extension reactions, righting or equilibrium reactions). The therapist pulls the child backward, allowing him to swing forward and backward through space until he stops, also up and down, and side to side movements were allowed. Each child

was asked to keep his balance, while he was moved through space. Duration of each exercise was 1–2 min with a time of rest (1–2 min) in between exercises [18].

The two groups in addition, received a designed exercises program for balance and posture control including the following items with clear instructions to the child to perform it:

1. Standing with feet together while the therapist sitting behind and manually locking the child knees, and then slowly tilt him to each side, forward and backward.
2. Step standing with therapist behind the child guiding him to shift his weight forward then backward alternately.
3. High step standing and try to keep balanced.
4. Standing with manual locking of the knees then tries actively to stoop and recover.
5. Equilibrium, righting and protective reactions training.

Since gait is an important dynamic balance component so gait training was important for balance retraining. The following exercises were performed:

- Forward, backward, and sideways walking between the parallel bars (closed environment gait training).
- Obstacles include rolls and wedges with different diameters and heights, were put inside parallel bars.
- Open environment gait training was conducted with the previous obstacles but without parallel bars.
- 6. Neurodevelopmental technique, proprioceptive training, facilitation of righting and equilibrium reactions, faradic stimulation on the antispastic muscles of the hemiparetic side, stretching exercise for the muscles liable to be tight, strengthening exercises for the antispastic muscles, and gait training in closed and open environment. Special attention was also given to the unaffected side and to the trunk.

3. Results

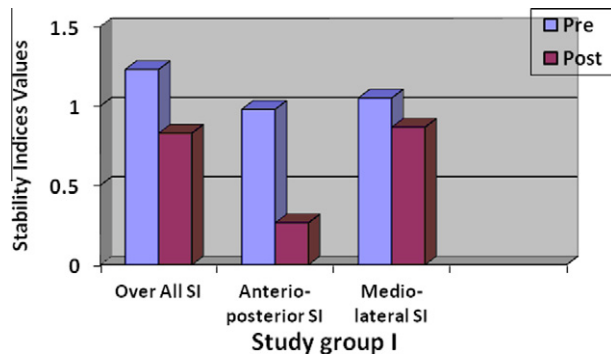
The collected data from this study represent the statistical analysis of the stability indices including overall stability index, antero-posterior (A/P) stability index and medio-lateral (M/L) stability index of the dynamic balance test at the level 8 stability (more stable platform) was measured before and after three months of treatment for the two groups. The raw data of the measured variables for the two groups were statistically treated to show the mean and standard deviation. Student *t*-test was then applied to examine the significance of the treatment conducted for each group. The obtained results in this study revealed no significant differences when comparing the pre-treatment mean values of the two groups. Significant improvement was observed in all the measuring variables of the two groups study I and study II, when comparing their pre and post-treatment mean values. After treatment significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group II.

As revealed from Table 1 and Fig. 1, significant reduction was observed in the mean values of stability indices for the study group I at the end of treatment as compared with the corresponding mean values before treatment.

Table 1 Pre and post-treatment mean values of the stability indices for the study group I.

	Stability indices					
	Over all SI		Antero-posterior SI		Medio-lateral SI	
	Pre	Post	Pre	Post	Pre	Post
\bar{X}	1.122	0.718	0.899	0.427	1.043	0.711
\pm SD	± 0.153	± 0.089	± 0.258	± 0.057	± 0.110	± 0.103
<i>t</i> -Test	2.893		2.657		8.123	
<i>P</i> -value	$0 < 0.05$		$0 < 0.05$		$0 < 0.0001$	
Sig.	Significant		Significant		Significant	

\bar{X} : mean, SD: standard deviation, *P*-value: level of significance, Sig.: significance, SI: stability index.

**Figure 1** Demonstrating the pre and post-treatment mean values of the stability indices of the study group I.

Also, Table 2 and Fig. 2, showed a significant reduction in the mean values of stability indices for the study group II at the end of treatment as compared with the corresponding mean values before treatment.

Significant improvement was also observed when comparing the post-treatment mean values of the stability indices of the two groups in favor of the study group II ($P < 0.05$) as shown in Fig. 3

4. Discussion

Impaired balance, gait disturbances and frequent falls are common problems in CP children. Cerebral palsy was found to demonstrate that deficits in postural control system that may provide a partial explanation for balance problems that are common in these subjects [19]. Recent meta-analysis found that abnormalities of gait or balance were the most consistent predictors of future falls [20].

Unruh [21] reported that children with CP have predominance of primitive, spinally controlled muscle responses patterns over more centrally integrated and coordinated movement patterns that is due to poor myelination of the descending cerebral and brain stem neurons and also reduction in both number and connection of the neurons in the higher nervous centers as motor cortex, basal ganglia, cerebellum and brain stem. The purpose of this study was to compare between the effect of whole body vibration and suspension therapy via using spider cage on balance in children with hemiparetic cerebral palsy. Conducting the study on children aged from 8 to 10 years may be attributed to the fact that, patients with CP between 7 and 14 years show defect in agility and

balance tasks [22]. This also comes in agreement with Westcott et al. [23] who confirmed that infant and young children (aged 4 months to 2 years) are dependent to the visual system to maintain balance, while at 3–6 years of age, children begin to use somatosensory information appropriate. Finally, at 7–10 years of age, children are able to resolve a sensory conflict and appropriately utilize the vestibular system as a reference. He added that, postural control is essentially adult like by about 7 to 10 years of age. This age group was chosen as they had significant practice of their functional activities and changes in anthropometrics would have been fairly steady for several years [10]. The Biodex stability system was used for evaluation using dynamic balance test which was performed on stability level 8. This agree with Revel et al. [24] who reported that, balance assessment should attempt to stimulate dynamic condition in order to stress the postural control system fully and reveal the presence of balance disorder. The pre-treatment mean values of overall stability index, antero-posterior stability index and mediolateral stability index of the dynamic balance test showed a significant increase in their values which indicated that those children had a significant balance problems.

The pre-treatment results of the present study were consistent with those reported by Testerman and Griend [25] who emphasized that the larger the numerical value of the stability index (represents the variance of platform displacement in degrees from level), the greater the degree of difficulty or instability in balancing the platform. This comes in agreement with Rozzi et al. [12] who concluded that, compared to low stability indices, high stability indices indicate greater platform motion during stance and therefore denoting less stability. The post-treatment results of the study group I reinforced the effectiveness of treadmill training on improving balance by adopting suitable program of treadmill walking.

This agrees with Fowler et al. [5] who recommended that the researches should be conducted to look at the long term effects of the whole body vibration on the child's ability to negotiate obstacles in their pathway while maintaining the dynamic balance because the parents suggest that children with CP are more prone to fall when encountering obstacles in their environment.

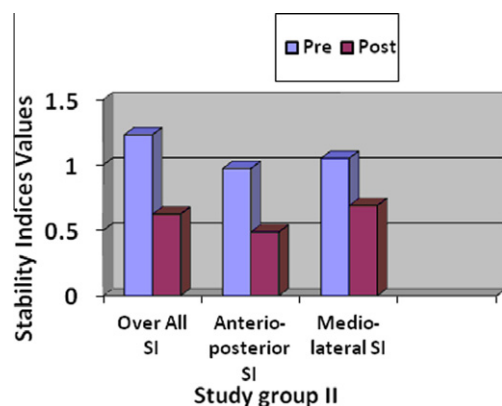
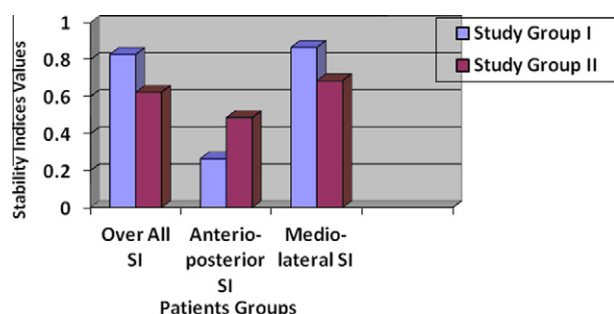
This also comes in agreement with Carmeli et al. [26] who relieved the effects of a treadmill walking program on muscle strength and balance in elderly people with CP.

The improvement seen in the study group I may be due to stepping practice via whole body vibration which strengthens and stabilizes the neural network involved in producing this pattern and improve the specific postural control mechanism

Table 2 Pre and post-treatment mean values of the stability indices for the study group II.

	Stability indices					
	Over all SI		Antero-posterior SI		Medio-lateral SI	
	Pre	Post	Pre	Post	Pre	Post
\bar{X}	1.239	0.623	0.972	0.487	1.053	0.686
\pm SD	± 0.149	± 0.073	± 0.256	± 0.066	± 0.092	± 0.075
<i>t</i> -Test	2.147		2.283		2.658	
<i>P</i> -value	$0 < 0.05$		$0 < 0.05$		$0 < 0.05$	
Sig.	Significant		Significant		Significant	

\bar{X} : mean, SD: standard deviation, *P*-value: level of significance, Sig.: significance, SI: stability index.

**Figure 2** Illustrating the pre and post-treatment mean values of the stability indices of the study group II.**Figure 3** Representing the post-treatment mean values of the stability indices for the two groups (study group I and study group II).

needed to maintain the balance when transferring the weight from one leg to the other, so, treadmill as an example for stepping practice, facilitates and strengthens the neural connections that arise from the coupling of multimodal sensory input generated by the child through improving attention and awareness of the body position image in relation to his or her environment [27]. The post-treatment results of the study group I also come in agreement with Mastsuno et al. [28] who concluded that the whole body vibration is considered as a moving surface, so, the children needed to spend more time with both feet on the surface during the walking cycle than when they walked over ground. Consequently, they spend less time with only one foot on the surface during treadmill walking than during over ground walking. He added that,

one factor that contributes to improve stability and balance is the increase in the base of support.

Our results contradict with Carmeli et al. [29] who assessed balance following ball exercises and treadmill training in adult persons with intellectual disability. There was a lack of improvement noted in both postural and balance control in those subjects as a result of 6 months of intervention. With respect to study group II who received suspension therapy via using spider cage, there was significant improvement in the mean values of stability indices. This improvement in the study group II may be attributed to the use of spider cage. It provided more stabilization to the child which minimized the displacement of center of pressure (COP) under each foot, so keeping the COP near the middle. In addition to that, it helped the child to keep small amplitude of COP motion and decrease postural sway which reflected a good balance control and tended to achieve quiet stance [30].

Also, the post-treatment results of the study group II may be attributed to the effect of spider cage on improving the agonist/ antagonist relationship of the lower limb muscles through loading and unloading (joints distraction and / or approximation) resulting in improvement of weight bearing activities through alteration of the proprioceptive sense. The results of this study come in agreement with Stillman [31] who reported that proprioceptive awareness of postures and movements is most required during the learning of new skills. He added that, with slower movements the proprioceptive system can monitor and adjust the movements as it occurs. This system is able to trigger immediate, rapid and precisely-tailored compensatory muscular contractions reflexively in response to unexpected changes in external or internal forces; for example as required during standing balance.

This confirms the findings of Keen [32] who reported that training with the use of spider cage helped the patient firstly to overcome the gravitational effect on their static, dynamic patterns and secondarily to modulate the muscle tone, which helped in keeping the body from collapsing.

It had been proved that there were abnormalities in the functioning of the vestibular apparatus of individuals with CP as the peripheral vestibular system including Scarpa's ganglion cells and vestibular hair cells, was affected [33,34]. This improvement in study group II may be due to the effect of suspension therapy in the development of equilibrium reaction to maintain and regain balance during standing pattern. This can be achieved primarily from vestibular input and secondary from proprioception and vision. If the speed or magnitude of displacement of the child's center of gravity is too great, vestibular, proprioception and vision (equilibrium reaction) will help

to regain balance in such cases. This treatment gives postural stability while promoting independence with security which significantly improves balance, coordination of the body and the performance of the vestibule system [35]. Improvement fulfilled in the study group I and study group II might be attributed to the effect of exercises therapy program for balance and postural control. This agrees with the findings of Carvalho and Almeida Gil [36] who suggested that proprioceptive information is essential for the motor control system to select the appropriate motor strategy of reciprocal activation among the agonist and antagonist to efficiently balance. Significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group II receiving suspension therapy via using spider cage. These results might be attributed to the effect of spider cage on improving the function of vestibular system. Stimulation of vestibular response provided by spider cage stimulates otolith organs through linear displacement. These findings come in agreement with Rine [37] who reported that stimulation of otolith organs by transient linear acceleration and/or by changes in head position with respect to gravity evoke phasic and tonic vestibule-ocular and vestibule-spinal reflexes, which act on the head and limbs to maintain posture. He added that orientation in space depends to a height extent on input from vestibular receptors, visual cues, impulses from proprioceptors in joint capsules and from cutaneous extra receptors especially those of touch and pressure. These four inputs are integrated at various levels of the nervous system to maintain posture. In conclusion, both whole body vibration and suspension therapy via using spider cage are effective in the treatment for hemiparetic cerebral palsied children with high recommendation for using suspension therapy.

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